Anatomy of the Sural Nerve and Its Relation to the Achilles Tendon by Ultrasound Examination

HAGUY KAMMAR, MD; MICHAEL R. CARMONT, MD; EUGENE KOTS, MD; LIOR LAYER, MD; GIDEON MANN, MD; MEIR NYSKA, MD; OMER MEI-DAN, MD

Full article available online at Healio.com/Orthopedics. Search: 20140225-64

Sural nerve injury is a relatively common complication after surgery on the Achilles tendon. Studies to determine the course of the sural nerve have been performed on cadaveric specimens. The purpose of this cross-sectional study was to use ultrasound to determine the relations of the sural nerve in a healthy population. The authors performed ultrasound examination of the posterior triangle of the ankle and Achilles tendon to determine the course of the sural nerve relative to the Achilles tendon in healthy participants. The mean distance between the nerve and the tendon was 21.48, 11.47, 5.8, and 0.81 mm lateral to the Achilles tendon as measured at the insertion and 4, 8, and 11 cm proximally, respectively. Male participants tended to have a nerve that was initially more lateral to the Achilles insertion compared with women. The distance between the sural nerve and the Achilles tendon was found to be lower in older participants, with the nerve passing significantly closer to the tendon at all levels ($P<.01$). Three anatomical variants were reported, with the nerve crossing the lateral border of the Achilles low or high or with multiple branches yet to converge. The course of the sural nerve can be visualized and plotted relative to the Achilles tendon using ultrasound examination in healthy participants. Older patients may be at an increased risk of iatrogenic nerve injury because the nerve courses closer to the Achilles tendon than that in young patients. Intraoperative ultrasound examination may be a useful modality to prevent sural nerve injury during Achilles tendon surgery.
The Achilles tendon can cause significant morbidity due to pathological change, tendinopathy, and rupture.\textsuperscript{1} Pain, thickening, and dysfunction of the Achilles tendon is termed Achilles tendinopathy\textsuperscript{1} and although effective treatment in the majority of patients consists of eccentric loading exercises\textsuperscript{2} and injections modalities,\textsuperscript{1} a significant proportion of patients proceed to surgical intervention. Injury is common within the sporting population and 66\% to 81\% of Achilles tendon ruptures are related to sporting activity.\textsuperscript{3,4}

Surgery on the Achilles tendon may be performed using open, minimally invasive, or percutaneous methods. Open surgery permits exploration of the course of the sural nerve, whereas other methods rely on knowledge of the course of the nerve and other modalities to determine the course of the nerve during surgery. Percutaneous repair of Achilles tendon rupture reduces overall surgical complications of the procedure and reduces hospital stay and costs but has a higher rate of nerve injury of up to 60\%.\textsuperscript{5,6}

Studies reporting the anatomy of the sural nerve and injury rates have been performed on cadaveric specimens or patients following nerve rupture.\textsuperscript{7-11} The medial sural cutaneous nerve and the peroneal communicating nerve\textsuperscript{10} merge to form the nerve as it passes from the outer aspect of the foot.\textsuperscript{10,12} The nerve then passes beneath the tip of the lateral malleolus before curving posteriorly toward to the Achilles, passing 18.8 mm anterior to the Achilles insertion.\textsuperscript{10} The nerve then courses superiorly within the subcutaneous tissues to cross the lateral margin of the Achilles tendon at approximately 8 to 10 cm from the insertion.\textsuperscript{13}

Surgery may be performed based on these findings; however, the normal relationships of the nerve in cadaveric specimens may be altered due to tissue contraction during the preservation process.\textsuperscript{14} Alternatively, the defect created by separated tendon ends may draw the nerve from its original position in cases of rupture, and the local soft tissue swelling in Achilles tendinopathy and paratendinopathy may displace the nerve laterally.

The purpose of this cross-sectional study was to use ultrasound to determine the relations of the sural nerve to the Achilles tendon in a healthy population. Ultrasound may assist in planning of the surgical procedures and may reduce the rate of iatrogenic sural nerve injuries.\textsuperscript{15,16}

**Materials and Methods**

The authors evaluated a group of 68 healthy participants. All participants gave informed consent for the study. Ethics approval was obtained prior to recruitment. During recruitment, participants were excluded if they had major trauma or lower limb surgery previously, Achilles pathology, or additional bone, nerve, or muscle disease.

All patients had ultrasound examination of the Achilles tendon and the sural nerve by an experienced musculoskeletal radiologist (E.K.) that was reviewed by an Orthopedic Sports Surgeon experienced in sonography (O.M.-D.). Ultrasounds were performed using a 7- to 12-MHz linear transducer HDI 5000 SonoCT ATL (Philips, Andover, Massachusetts). All participants were placed in a prone position with the knee at 10° flexion and the foot over the edge of the examination table. This prevented inadvertent ankle plantar flexion.

Participants had their heights and leg lengths measured. Leg length was measured from the tibial tuberosity to the tip of the medial malleolus. Ultrasound was performed to determine the course of the sural nerve. The distance between the medial border of the sural nerve and the Achilles tendon was determined at 4 predefined landmarks: “point zero” (0 cm), the most distal point measured and defined as the upper (most proximal) point of the insertion of the Achilles tendon into the calcaneus, and then additional measures were conducted at 4, 8, and 11 cm proximal to point zero (Figure 1). The distance from point zero to where the sural nerve crosses the Achilles tendon, from medial to lateral, was also measured on the lateral boarder of the tendon.

**Statistical Analysis**

Data were analyzed in relation to age, gender, activity, and leg dominance using univariate analysis of variance and $t$ tests. All statistical tests used 2-sided $P$ values, and the selected level of significance for all variables was alpha equal to .05. SPSS version 15.0 statistical software (SPSS Inc., Chicago, Illinois) was used to analyze the data.

**Results**

Sixty-eight participants were included in the study, and both legs were examined (136 legs). The study included 32 men and 36 women. Participants’ ages ranged from 16 to 60 years (mean: 35.8 years; SD: 15.5 years), and participants were divided into 2 age groups for comparison: young (range: 16-39 years, mean: 22.1 years, SD: 6.6; n=34) and old (range: 40-60 years, mean: 49.9, SD: 6.5; n=34). The gender distribution within each group was 17 (50\%) men and 17 (50\%) women in the young group and 15 (44\%) men and 19 (56\%) women in the old group.

No difference was found between the left and right legs. The sural nerve was found to cross the Achilles tendon from medial to lateral at a mean of 11.68 cm proximal to its insertion at the calcaneus. Mean distance between the nerve and the tendon was 21.48, 11.47, 5.8, and 0.81 mm lateral to the Achilles tendon as measured at the insertion and 4, 8, and 11 cm proximally, respectively (Table).

The distance between the Achilles tendon and the sural nerve increased with the participant’s height ($P<.05$). Height was also correlated positively with the crossing point of the sural nerve and Achilles tendon from the Achilles insertion point zero ($P<.001$). Although a statistically significant difference in height between genders was observed (men, 176.85 cm; women, 170.65 cm; $P=.003$), no difference in dis-
Age was found to be a significant factor. The sural nerve passed significantly closer to the Achilles tendon in older participants group (P<.01). The delta calculated between the measured distance at point zero and 4 cm (point zero—4 cm) was found to be significantly larger in men (13.07 mm) than women (10.66 mm) (P<.05).

In addition, 3 common anatomical variations of the sural nerve track were identified alongside the Achilles tendon (Figure 2):

- Variation 1: The sural draws away from the tendon in a constant splay (67%—most frequent variation).
- Variation 2: The sural descends (proximal to distal) parallel to the tendon immediately after it crosses its lateral border, and then drawing away from the tendon 4 cm proximal to point zero (23%—second most frequent variation).
- Variation 3: The sural descends parallel (but not adjacent) to the tendon where, at 4 cm proximal to point zero, it draws farther away from the tendon (10% frequency).

This ultrasound study reports a similar location of the sural nerve to those reported in anatomical cadaveric studies and the position as described during surgical dissection. Given the noninvasive nature of this study, the authors were able to localize the course of the nerve on a relatively large number of participants and noted variations in terms of age and height. The nerve was found to track closer to the Achilles tendon in older and shorter participants and to cross it from medial to lateral more proximally in taller participants. No gender differences were observed, although men tended to have a nerve that was initially more lateral to the Achilles at its insertion than that in women. This suggests that the risk of injuring the nerve may be greater in older, shorter women.

The authors have described 3 common anatomical variations of course of the sural nerve in relation to the Achilles tendon. The information is of benefit to all who operate on the Achilles tendon and its associated structures. Flavin et al suggested an ultrasound mapping of the sural nerve as a valid imaging method. Ultrasound mapping is relatively inexpensive, involves no radiation, and can be done at bedside or in the operating room, with minimal logistic requirements. Conversely, ultrasound examination is operator dependent and requires regular practice to be familiar with musculoskeletal imaging and normal values. In this series, an experienced radiologist performed the ultrasound examinations accompanied and reviewed by an orthopedic sports surgeon experienced in ultrasound in an attempt to minimize intraobserver error.

Knowing the safe distance between the tendon and the nerve is useful information for the surgeon during surgical planning and exploration of the nerve during surgery because damage to the sural nerve will result in sensory deficit and will affect surgical outcomes. However, injury or pathology may be present for the surgery to even be required and as a result this will distort the position of the nerve. The presence of hematoma and edema may make the nerve more difficult to visualize on ultrasound, particularly if the examination is undertaken by an inexperienced operator.

This study does have a few limitations. Despite the large group and the various ages studied, the cohort might be considered to have some bias. Part of the sample of participants consisted of professional female volleyball players and although a wide range...
of player heights were noted, the majority would be considered tall compared with a standard patient population. In addition, during ultrasound examination, formal measurements of the knee flexion angle were not taken but were approximated to allow for a comfortable position during examination. This may have resulted in a slightly different knee position between participants and varying nerve tension. A comfortable position was essential for accurate ultrasound examination and distance measurement. The authors believe that these factors had little influence on the measurements and final results.

In general, the findings suggest that the sural nerve lies closer to the Achilles tendon in shorter and older patients, increasing the surgical risk of iatrogenic injury during surgery. This may provide additional information for the patient during the consent process. The discovery and description of the variations of the course and branches of the nerve reminds surgeons that care should be taken with localized dissection even after the main branch has been identified and protected intraoperatively. In turn, this knowledge should lead to a reduced rate of both partial and complete sural nerve injuries.

CONCLUSION

The authors have determined the relationship between the sural nerve and the Achilles tendon in healthy participants using ultrasound. It was demonstrated that ultrasound can accurately determine the sural nerve track and its distance from the Achilles tendon in a cheap and reproducible manner. Although the sural nerve is a sensory nerve, its injury might cause a variety of sensory disturbances from mild numbness to severe neuropathic pain. This study provides a baseline for the position of the sural nerve in healthy participants and in the future the intraoperative use of ultrasound may be used to visualize the sural nerve during surgery to minimize the risk of nerve injury.

REFERENCES